Future of Energy Security

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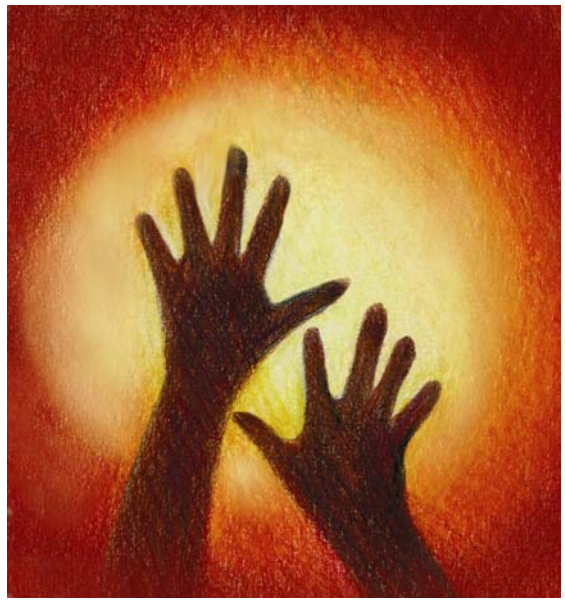


2 billion in 21st century

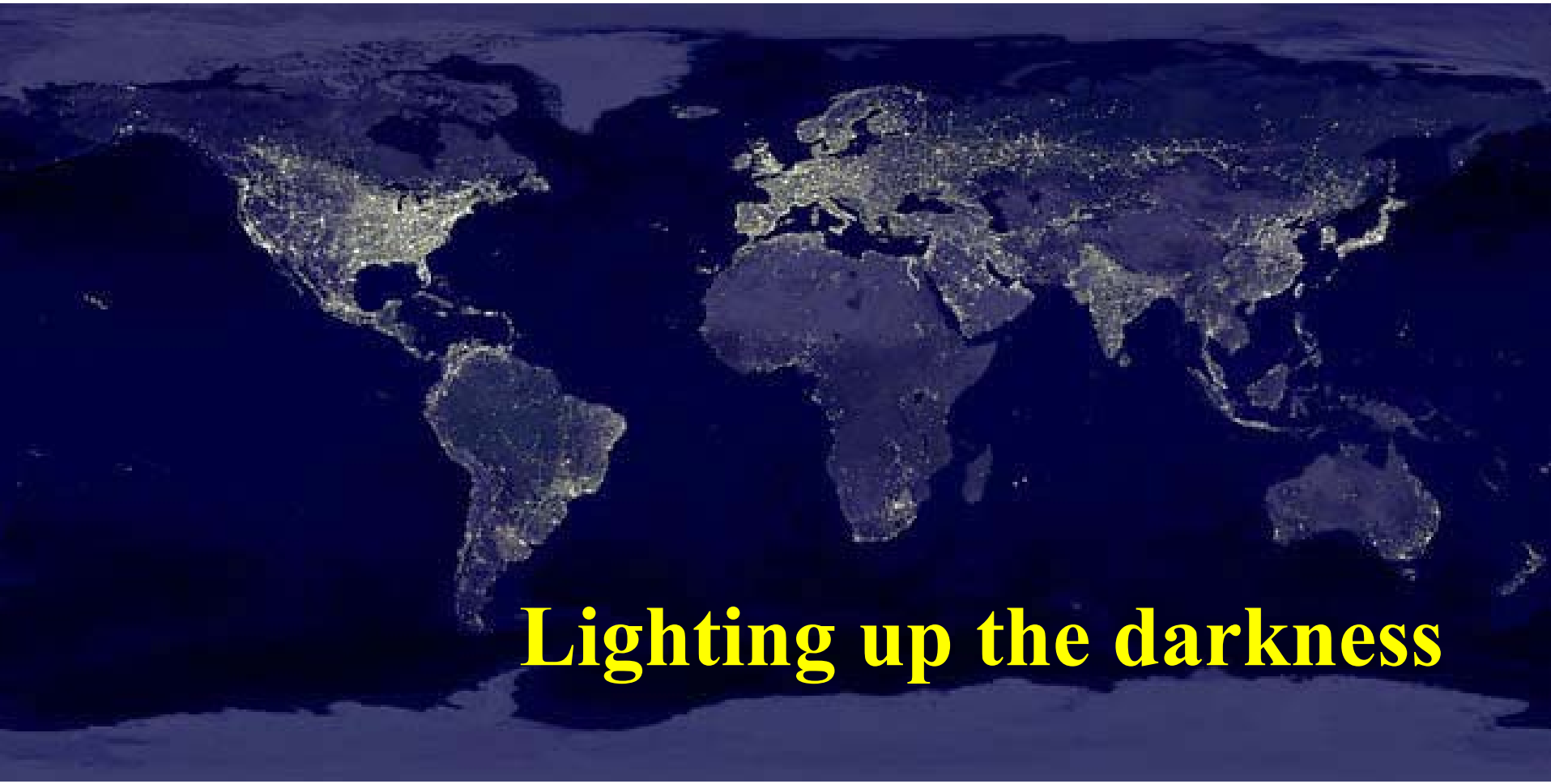
Resources & Skills

1.5B people in transition

3 billion in 18th century with less than $2 per day

(population growth is happening here)

3 billion people live on less than $2 per day



6 hours per day of "electricity" to the poor (women) will change their lives and the world

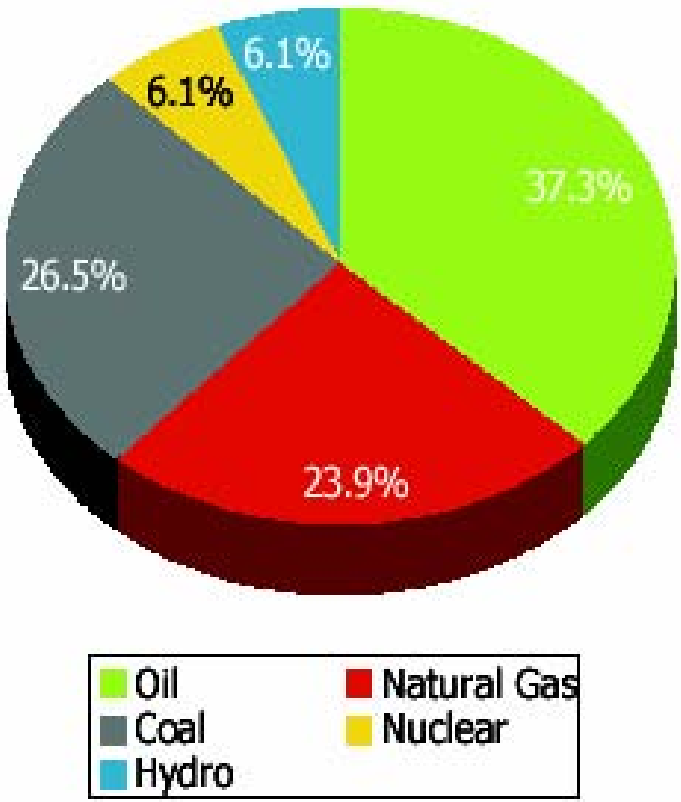
A mind-boggling global infrastructure (~$15 trillion) provides energy/mobility to ~3.5 billion people

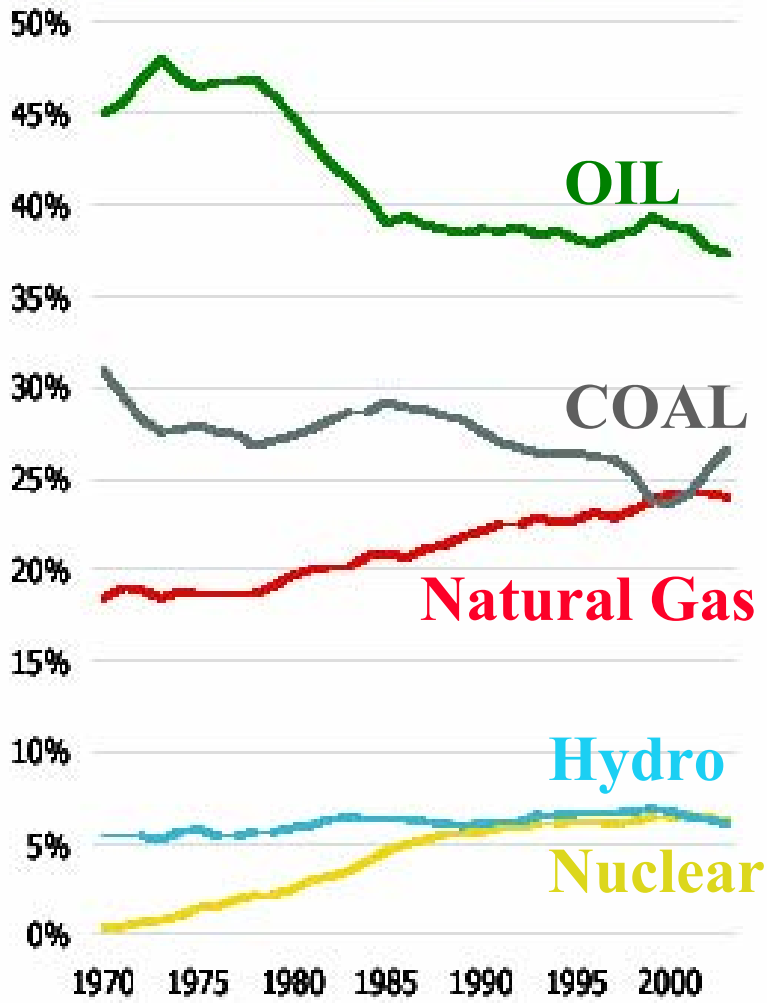
- Oil and gas contracts, rigs, exploration technology
- Tankers and pipelines
- Refineries, LNG facilities
- Auto industry
- 600 million cars running on gasoline
- Service stations and gasoline stations
- Existing coal/gas electricity generation plants

This cannot be changed overnight!

current and historical global energy mix

Current global energy supply is dominated by fossil fuels – oil has been the largest component of the energy mix for many decades; gas has grown strongly since the 1970's; coal has been growing in the last four years; hydro is constant and nuclear has plateaued





Source: BP Statistical Review

Fossil fuels and Environment

In the 20th century we started to act on pollution (mercury, NOx, SOx, acid rain, soot, ...) but <u>not</u> Green House Gasses like CO_2 and the associated global climate change

Climate change is the largest, costliest, most dangerous, uncontrolled experiment ever done by mankind

Immediate problems with business as usual

- USA imports 2/3 of oil used
- Share of imported natural gas (15%) set to increase rapidly
- Market saturated, volatile, unstable
- CO_2 emissions $\rightarrow$ global warming

Today, global consumption is 13 trillion watts of primary power

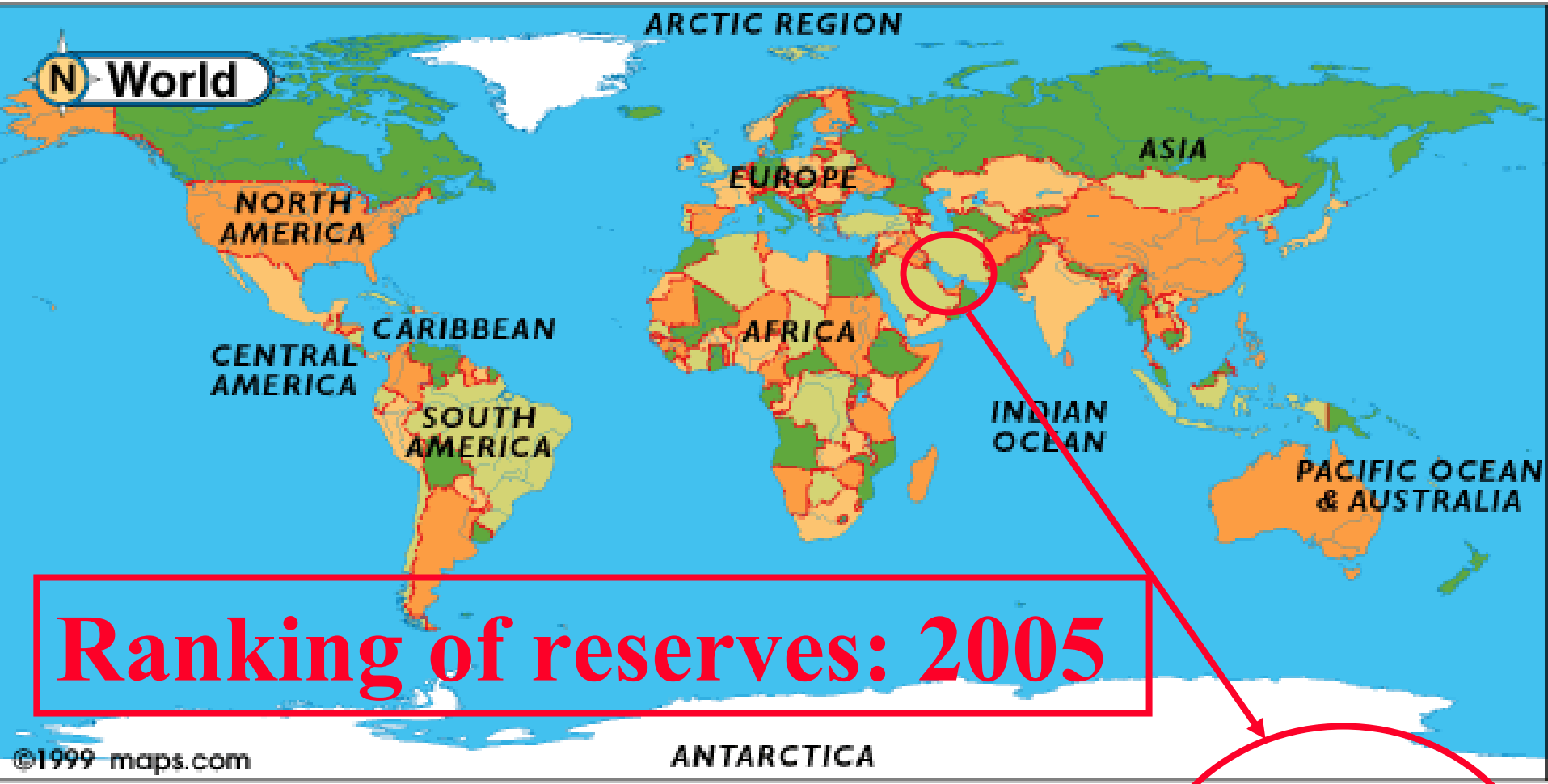
To sustain adequate standard of living for the 8 billion people expected by 2025, and without improvements in efficiency, we need 2.5 times today's energy.

Goal: 32 terawatts of cheap clean power

Cannot have cheap clean energy for all without some key S&T breakthroughs

- Separation/capture of CO_2 from mixed gas streams
- Secure and effective long-term storage of CO_2.
  - Geologic, mineralization, air extraction, …
- Hydrogen from non-fossil fuels (also fuel cells):
  - Electrolysis of water (inexpensive and efficient electrodes)
  - Photochemical and/or thermo-chemical splitting of water
- Reprocessing of spent nuclear fuel
  - separation of SNF, transmutation, reassembly into fuel
- Photovoltaic cell technology
  - nano and/or bio materials
- Fusion?

The world has changed, and is changing very rapidly



Ranking of reserves: 2005

USA 12,6,1

China 11,-,3

EU -, -, 4

Russia 8,1,2

India -, -, 5

AT -, -, -

Persian Gulf

OIL 1,2,3 4,5

GAS 2,3,4, 5,10

No Coal

Fast forward to 2020

USA ?,-,1

China -,-,3

EU -, -, 4

Russia ?,1,2

India -, -, 5

AT -, -, -

? → EOR

Persian Gulf

OIL 1,2,3 4,5

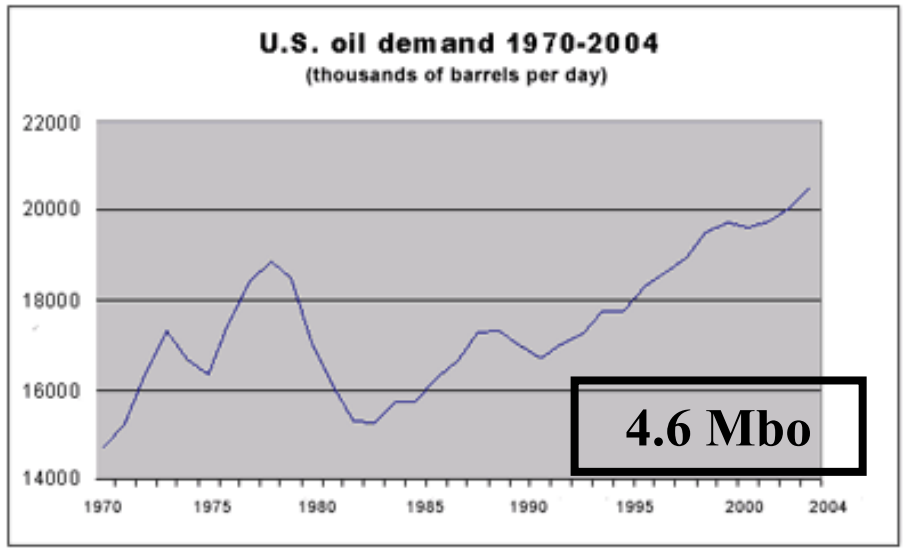
GAS 2,3,4, 5,9

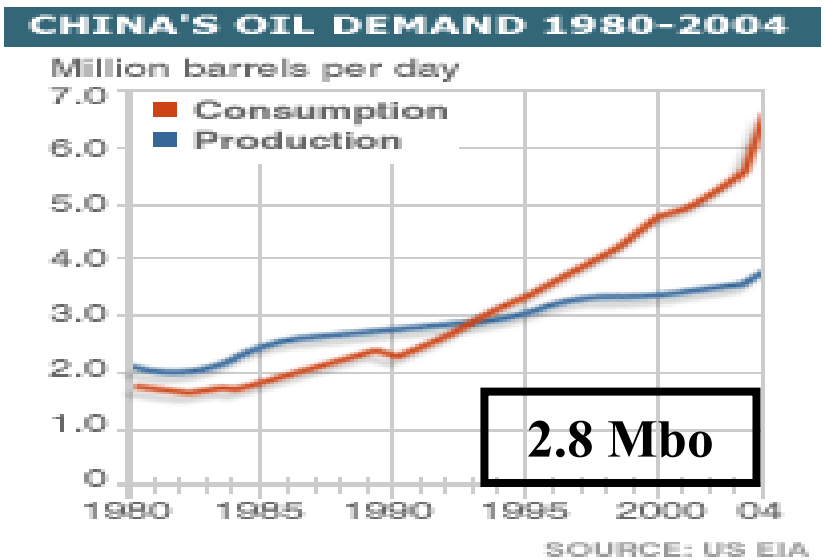
No Coal

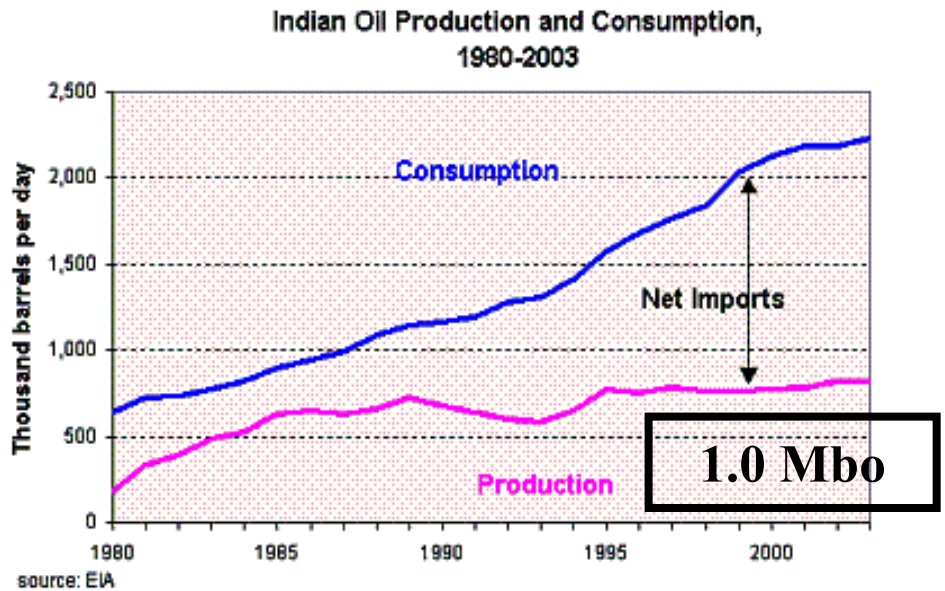
Middle East and Russia control conventional natural gas and oil

Constrains on supply

- Competition as a result of growth in demand (USA, China, India since 1990)
- Little excess capacity
- Major disruptions
- Exploration, development and production not in the hands of oil companies





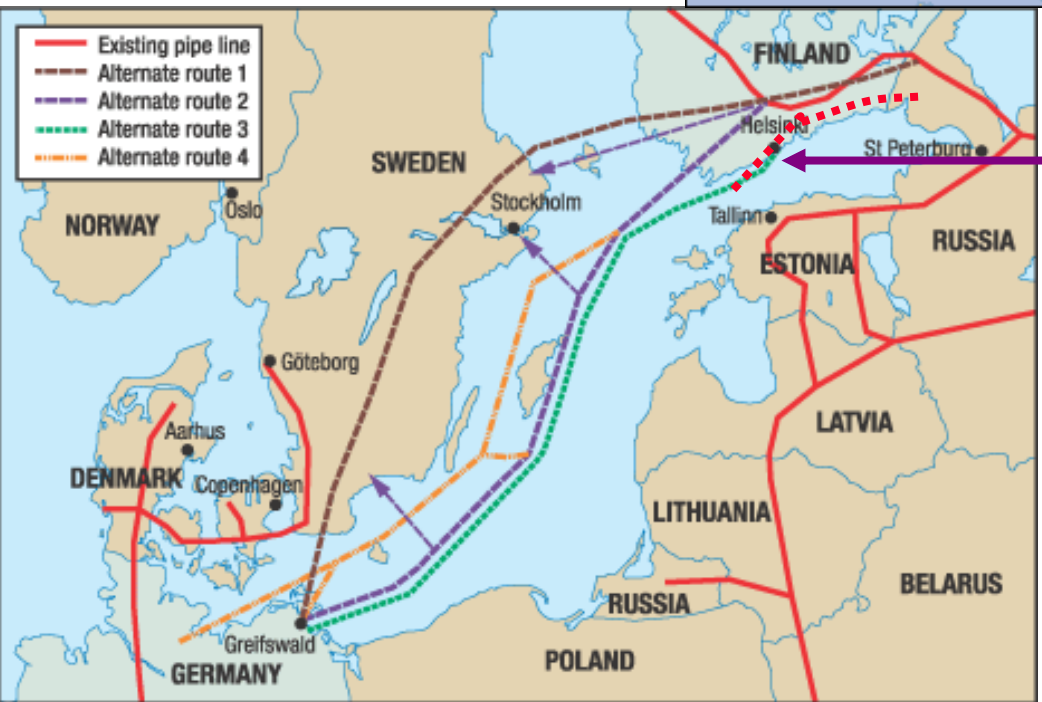


Rapidly changing world – Geopolitics

- Nationalization of oil and natural gas fields (Venezuela, Bolivia, Nigeria, ...)
- New and evolving environmental regulations
- Difficult arrangements between nations with resources and oil companies
- Investments in unstable countries (Nigeria, Chad, Sudan, Angola, Iraq, Iran, Venezuela)
- Disruption of production and supplies (Iraq, Nigeria, Venezuela)
- The emerging role of Russia, Iran

He who owns the pipe lines gets the oil and gas!

Which countries will get Russian natural gas in 10 years time?



New pipeline from Vyborg, Russia to Griefswald, Germany bypasses Ukraine and Eastern Europe

Russia has muscle and cash: President Vladimir V. Putin

- (4/26/06 in Tomsk with Chancellor Merkel)
  "Russia should direct future oil and natural gas exports to Asia because *unprincipled competition* had blocked its energy companies from expanding elsewhere"
- (3/10/06 first presidential visit to Algeria)
  A $4-billion arms contract, the biggest in post-Soviet history. Plus contracts worth $1 billion involving natural gas company Gazprom and the oil company LUKoil, …. **(gas cartel?)**

Even if we get all the fossil fuel we want we still need to solve pollution and CO_2 problems. *Need action starting today*

- Need large-scale sequestration of CO_2 by 2020
- Need alternatives to fossil oil, coal, natural gas as energy source/carrier/storage

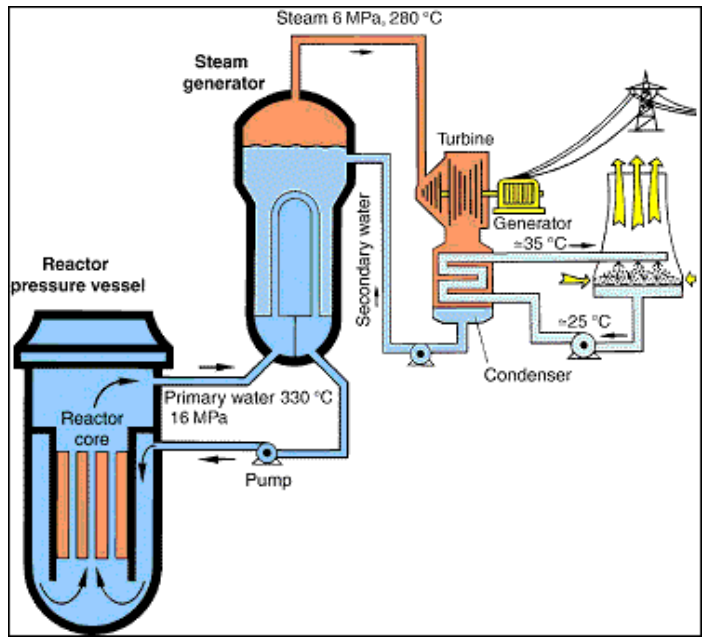
Tipping points reached

- **Excess food crops → ethanol**
  - **Economical at > $40 per barrel**
  - **3-5% solution for the USA**
- **Cellulose (waste) → ethanol**
  - **Economical at > $60 per barrel**
  - **3-5% solution for the USA**
- **Solar (homes and buildings at $10/peak watt)**
  - **Cost recovery over lifetime (25-30 years)**
- **Wind (off-shore & on-shore)**
  - **part of a larger on-demand system**
- **Hybrid cars (35→50 miles per gallon)**
  - **$4K premium recovered over 150K miles @ $3/gallon**

Nuclear power "CO_2 clean"

Not in my backyard

- Principles of nuclear fission are known
- Natural ^{235}U is a limited resource
- Generation IV reactors
- Breeder reactors?
  - $^{232}Th \rightarrow {}^{233}U$
  - $^{238}U \rightarrow {}^{239}Pu$
- **Accidents**
- **Proliferation HEU, ^{239}Pu**
- **SNF reprocessing/management**



Examining energy futures from all three perspectives

- **National and International Security**
- **Cost, Economics and Development**
- **Environment**

Be more efficient
Sequester CO_2
Develop alternatives to fossil fuels

Energy Security
is
National Security
and
Economic security
and
Environmental Security

= Future of our children

Senator Lugar: "energy is the albatross of U.S. national security"

Brookings: 13 March 2006

Questions? (SFI, NREL)

- Globalized world – can free markets create stability in supply and demand? or equity?
- Can competition in a resource limited world foster co-operation?
- Social and political dynamics
- Future demand: as we urbanize, develop
- Population growth, demographics, migration
  - Especially if developing countries fail
- Impact of catastrophic events – resilience?
- Without cheap oil and gas - what after 2050?

Missing an Economic Opportunity

- **Clean Energy**
- **Low loss electric power grids**
- **Fuel for Transportation**
- **Efficient machines/appliances**

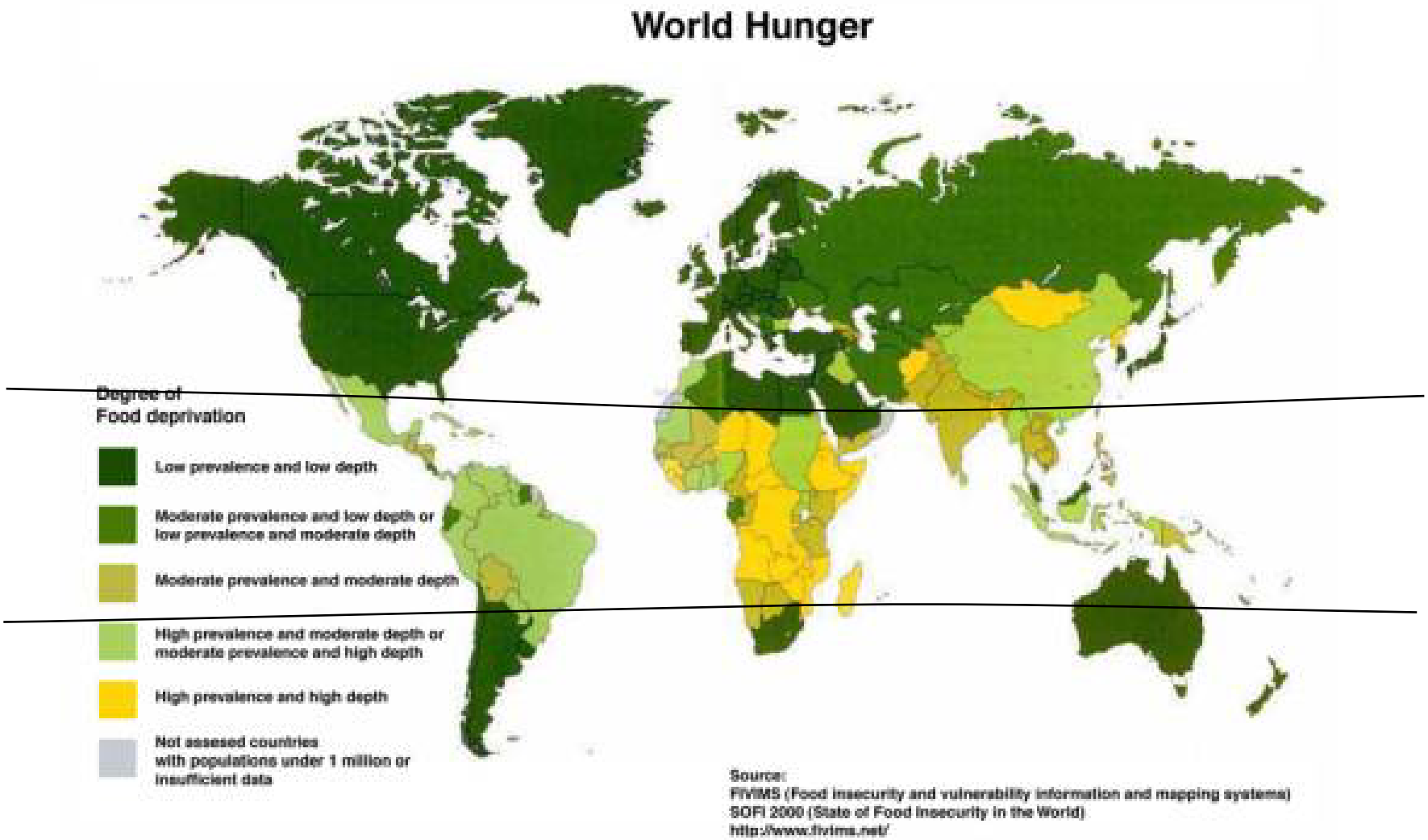
are increasingly value-added products.

32 Terawatts of global power demand translates into a $38 billion/day market at $0.05 kW hour

Industrialized nations must lead the R&D for cheap clean energy (= hope) for all mankind

Hope for the future!

Wind and solar are the most abundant sources of energy in poor countries lying within the tropics. Having exhausted cheap oil and gas, we owe them clean and cheap energy.



Further reading and Sources

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